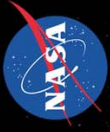


NASA'S EXPLORATION ARCHITECTURE

Timothy Tyburski
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio



A Bold Vision for Space Exploration



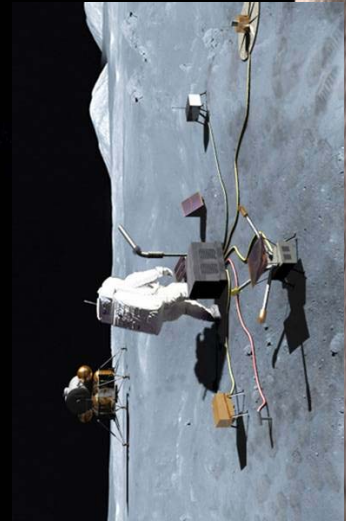
- ◆ Complete the International Space Station
- ◆ Safely fly the Space Shuttle until 2010
- ◆ Develop and fly the Crew Exploration Vehicle no later than 2012
- ◆ Return to the moon no later than 2020
- ◆ Extend human presence across the solar system and beyond
- ◆ Implement a sustained and affordable human and robotic program
- ◆ Develop supporting innovative technologies, knowledge, and infrastructures
- ◆ Promote international and commercial participation in exploration



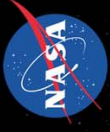
"It is time for America to take the next steps."

Today I announce a new plan to explore space and extend a human presence across our solar system. We will begin the effort quickly, using existing programs and personnel. We'll make steady progress – one mission, one voyage, one landing at a time"

*President George W. Bush –
January 14, 2004*



The Moon - the 1st Step to Mars and Beyond....



◆ Gaining significant experience in operating away from Earth's environment

- Space will no longer be a destination visited briefly and tentatively
- “Living off the land”
- Field exploration techniques
- Human support systems
- Dust mitigation and planetary protection



◆ Developing technologies needed for opening the space frontier

- Crew and cargo launch vehicles (125 metric ton class)
- Earth entry system – Crew Exploration Vehicle
- Mars ascent and descent propulsion systems (liquid oxygen / liquid methane)



◆ Conduct fundamental science

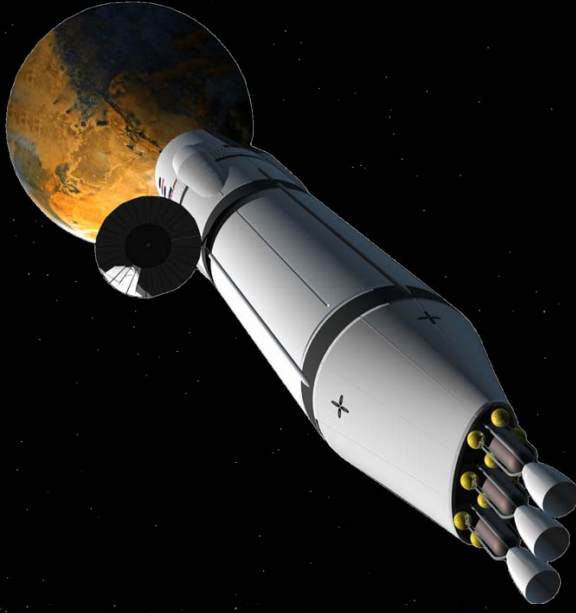
- Astrobiology, historical geology, exobiology, astronomy, physics

Next Step in Fulfilling Our Destiny As Explorers

How We Will Get to Mars

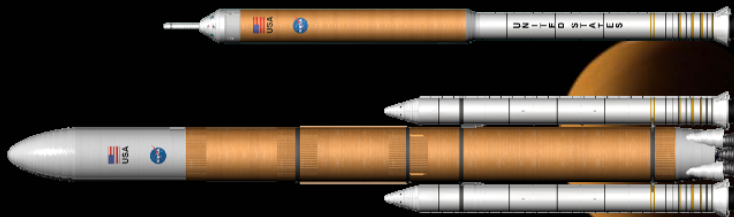
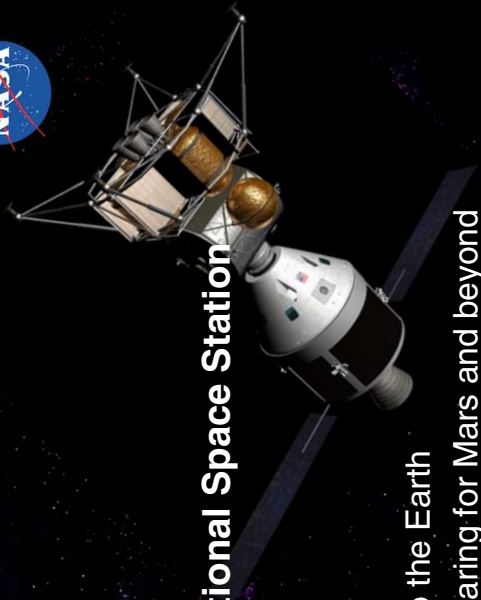
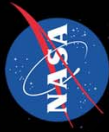


- ◆ 4 – 5 assembly flights to low Earth orbit with a 100 metric ton class launch system
- ◆ Pre-deployed Mars surface outpost before the crew launches
 - Habitat and support systems
 - Power
 - Communications
 - Mars ascent / descent vehicle
- ◆ 180 day transit time to/from Mars
 - 6 crewmembers
 - Dedicated in-space crew transit vehicle
 - Dedicated Earth entry system (CEV)
- ◆ 500 days on the surface
 - Capability to explore large regions of the surface
 - Multi-disciplinary science investigations
 - In-Situ resource utilization
 - Consumables: Oxygen and water
 - Propellants: Liquid oxygen and methane

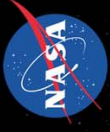


A Safe, Accelerated, Affordable and Sustainable Approach

- ◆ **Meet all U.S. human spaceflight goals**
- ◆ **U.S. system capable of servicing the International Space Station**
- ◆ **Significant advancement over Apollo**
 - Double the number of crew to lunar surface
 - Four times number of lunar surface crew-hours
 - Global lunar surface access with anytime return to the Earth
 - Enables a permanent human presence while preparing for Mars and beyond
 - Can make use of lunar resources
 - Significantly safer and more reliable
- ◆ **Minimum of two lunar missions per year**
- ◆ **Provides a 125 metric ton launch vehicle for lunar and later Mars missions and beyond**
- ◆ **Higher ascent crew safety than the Space Shuttle**
 - 1 in 2,000 (1 in 1,700 to 4,200) for the Crew Launch Vehicle
 - 1 in 220 (1 in 160 to 310) for the Space Shuttle
- ◆ **Orderly transition of the Space Shuttle workforce**
- ◆ **Requirements-driven technology program**



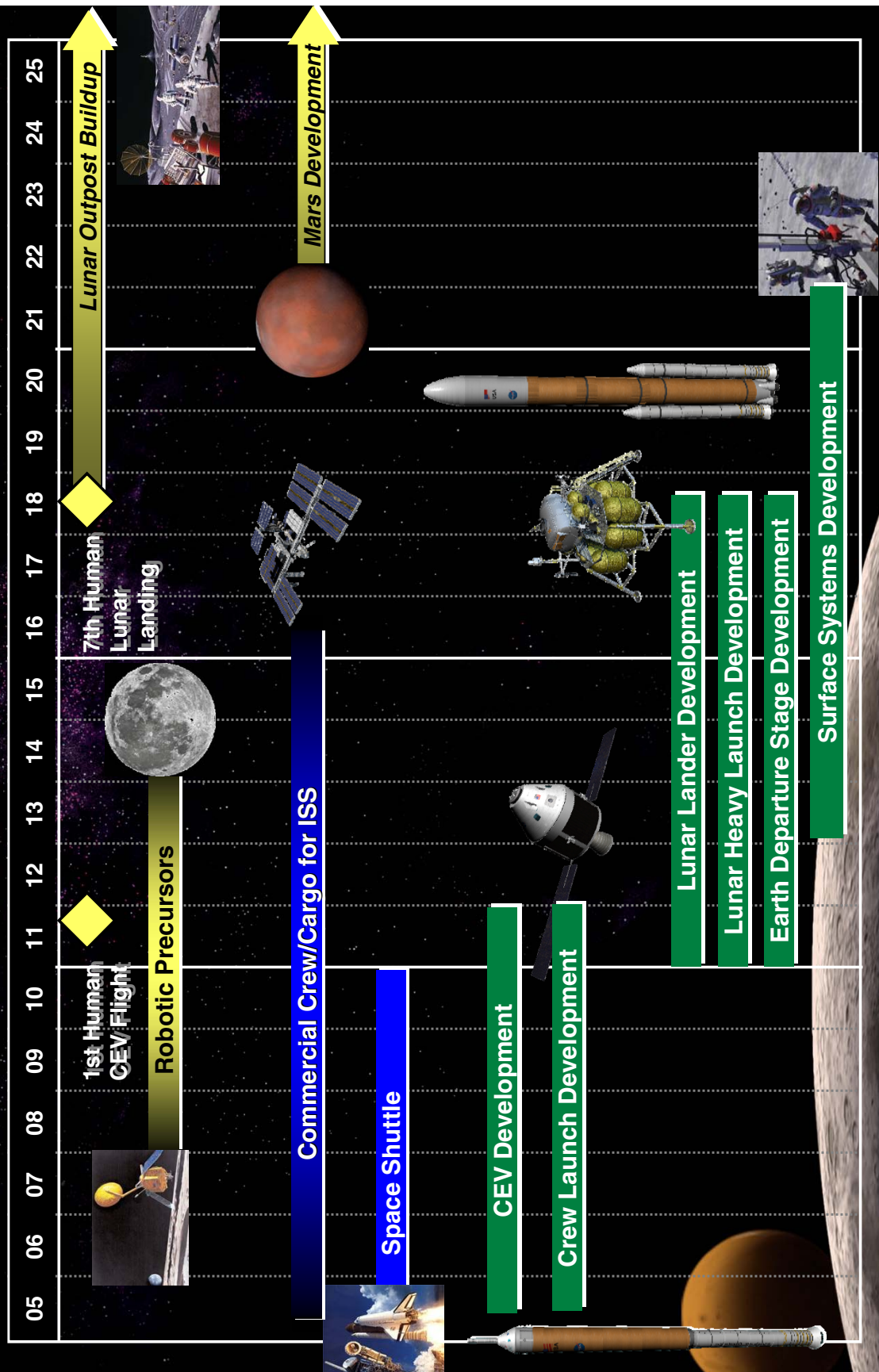
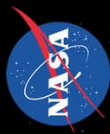
Human Exploration Missions



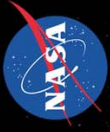
- ◆ ***Crew to and from the lunar surface***
 - 7 day missions to anywhere on the surface
 - Crew rotation to lunar outpost
- ◆ ***Cargo to the lunar surface***
 - One-way delivery of cargo to support longer duration missions
- ◆ ***Crew to and from Mars***
 - 500 days on the surface
- ◆ **International Space Station resupply capability – if commercial services are unavailable**
 - Ferry crew up and down
 - Cargo up and down



NASA's Exploration Roadmap



Paving the Way – Robotic Precursor Missions



◆ **Provide early information for human missions to the Moon**

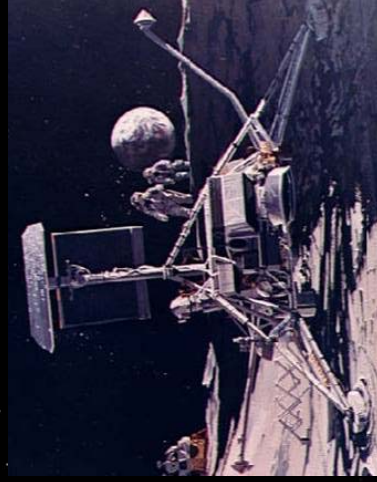
- Key knowledge needed for human safety and mission success
- Infrastructure elements for eventual human benefit
- Scientific results to guide human exploration

◆ **May be evolvable to later human systems**

◆ **Most unknowns are associated with the North and South Poles – a likely destination for a lunar outpost**

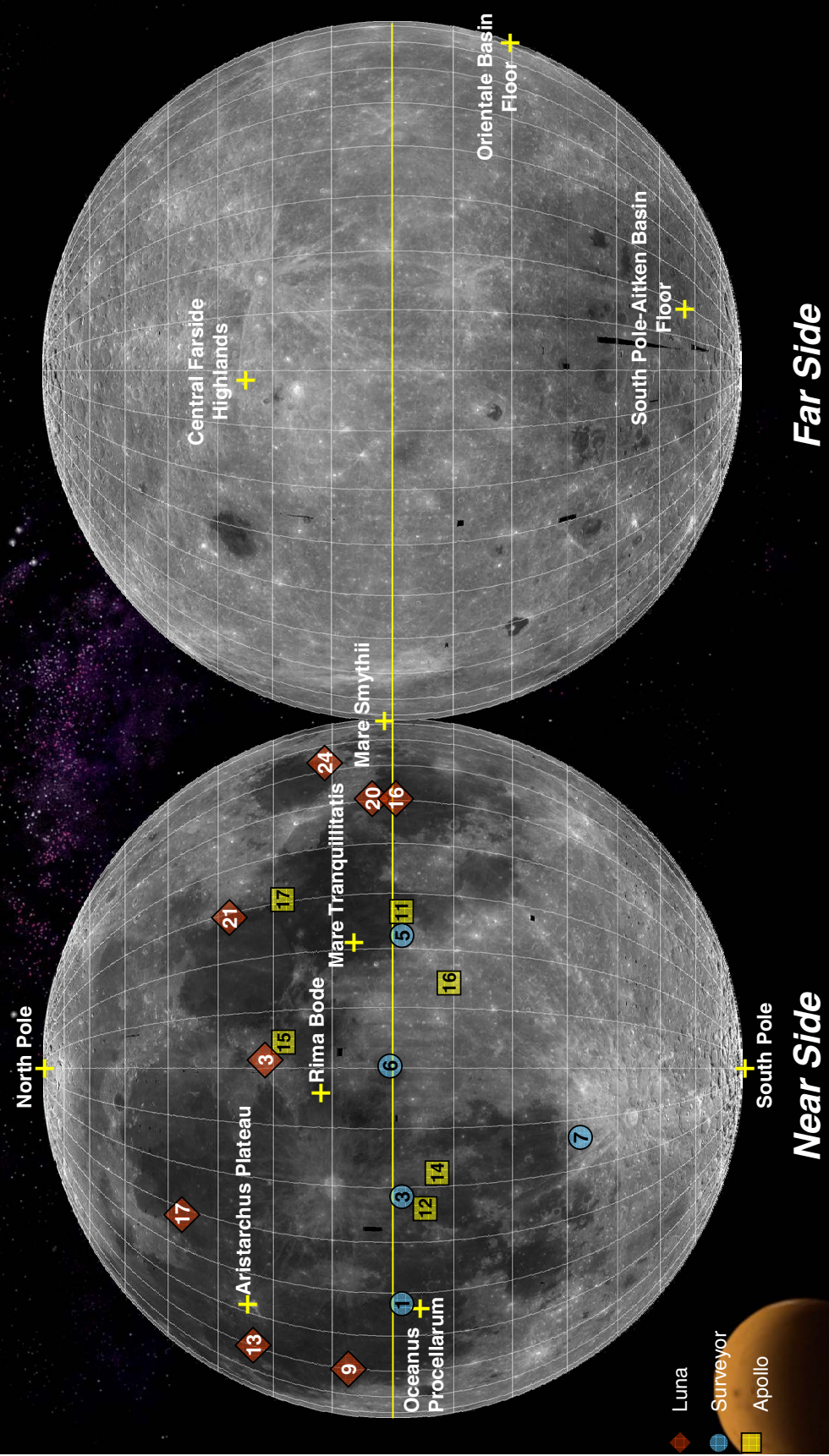
◆ **Key requirements involve establishment of**

- Support infrastructure – navigation/communication, beacons
- Knowledge of polar environment – temperatures, lighting, etc.
- Polar deposits – composition and physical nature
- Terrain and surface properties





High Priority Lunar Exploration Sites

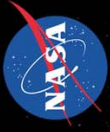


Far Side

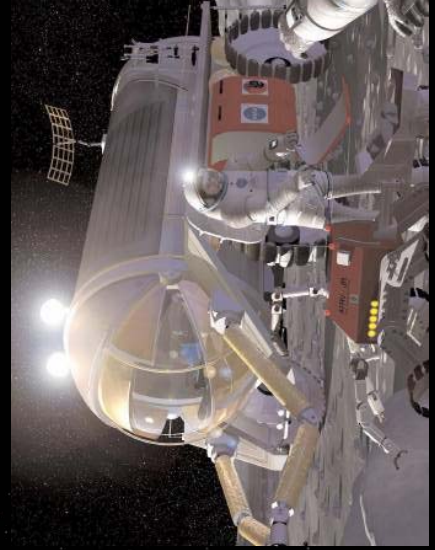
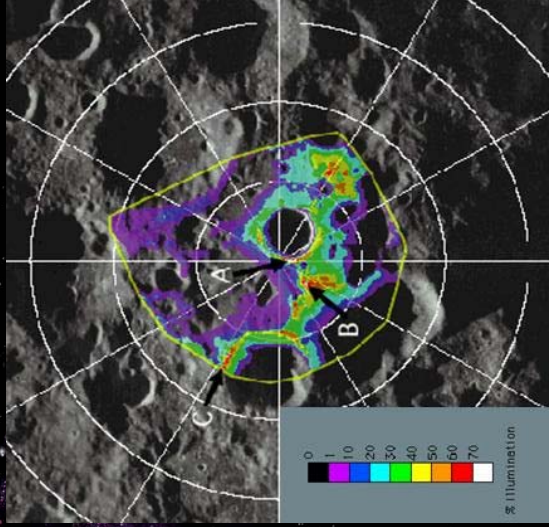
Near Side

- Luna
- Surveyor
- Apollo

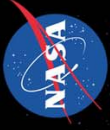
Possible South Pole Outpost



- ◆ The lunar South Pole is a likely candidate for outpost site
- ◆ Elevated quantities of hydrogen, possibly water ice (e.g., Shackelton Crater)
- ◆ Several areas with greater than 80% sunlight and less extreme temperatures
- ◆ Incremental deployment of systems – one mission at a time
 - Power system
 - Communications/navigation
 - Habitat
 - Rovers
 - Etc.



Lunar Surface Activities



◆ **Initial demonstration of human exploration beyond earth orbit**

- Learning how to operate away from the Earth



◆ **Conduct scientific investigations**

- Use the moon as a natural laboratory
 - Planetary formation/differentiation, impact cratering, volcanism
- Understand the integrated effects of gravity, radiation, and the planetary environment on the human body



◆ **Conduct in-situ resource utilization (ISRU) demonstrations**

- Learning to “live off the land”
- Excavation, transportation and processing of lunar resources



◆ **Begin to establish an outpost - one mission at a time**

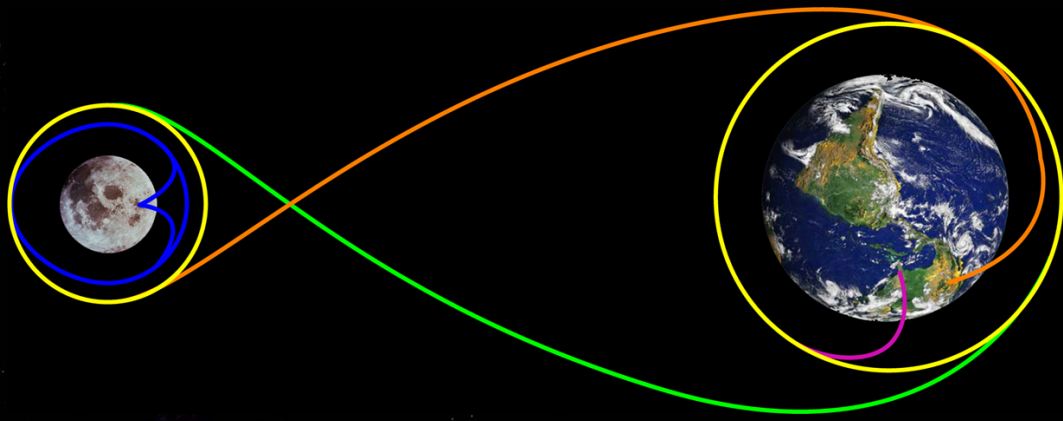
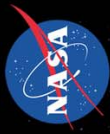
- Enable longer term stays



◆ **Testing of operational techniques and demonstration of technologies needed for Mars and beyond....**

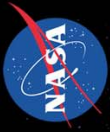
How We Plan to Return to the Moon **Mission Mode – “EOR-LOR”**

- ◆ After launch, the elements that take the crew to lunar orbit perform an “Earth Orbit Rendezvous (EOR)”
- ◆ At the completion of lunar surface activities the elements perform a “Lunar Orbit Rendezvous (LOR)” and return to Earth
 - “Direct Return” eliminated because it increases crew system complexity, has small margins, has the greatest number of operations issues and highest sensitivity to mass growth
- ◆ High efficiency cryogenic lander propulsion is an enabler
- ◆ The Crew Exploration Vehicle only *has to be* qualified for one launch system
- ◆ Mode has the highest calculated mission reliability and safety

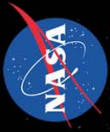


Lunar “Flight Plan” – Getting to the Moon

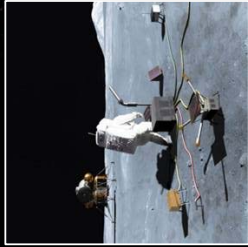
- ◆ Heavy lift launch of the Earth departure stage and lander
- ◆ Launch of the Crew Exploration Vehicle (CEV)
- ◆ CEV docks with earth departure stage / lander in low Earth orbit
- ◆ Transfer to the moon
- ◆ CEV and lander arrive in low lunar orbit
- ◆ Lunar landing



Lunar “Flight Plan” – Returning to Earth



◆ Lunar surface activities



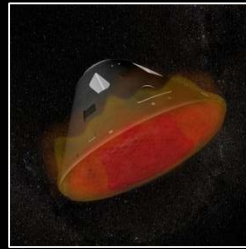
◆ Ascent from the surface



◆ Ascent stage docks with CEV in low lunar orbit and returns to Earth



◆ CEV enters the Earth’s atmosphere

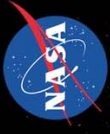


◆ CEV recovery

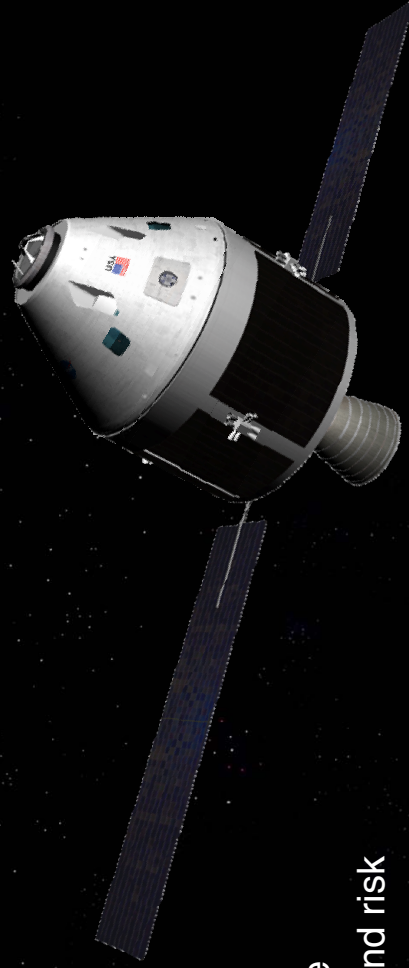


How We Plan to Return to the Moon

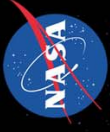
Crew Exploration Vehicle



- ◆ **A blunt body capsule is the safest, most affordable and fastest approach**
 - Separate Crew Module and Service Module configuration
 - Vehicle designed for lunar missions with 4 crew
 - Can accommodate up to 6 crew for Mars and Space Station missions
 - System also has the potential to deliver pressurized and unpressurized cargo to the Space Station if needed
- ◆ **5.5 meter diameter capsule scaled from Apollo**
 - Significant increase in volume
 - Reduced development time and risk
 - Reduced reentry loads, increased landing stability and better crew visibility



Servicing the International Space Station



◆ NASA will invite industry to offer commercial crew and cargo delivery service to and from the Station

◆ The CEV will be designed for lunar missions but, if needed, can service the International Space Station. Annually, the CEV has the potential for:

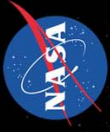
- 2 crew flights
- 3 pressurized cargo flights
- 1 unpressurized cargo flight

◆ The CEV will be able to transport crew to and from the station and stay for 6 months

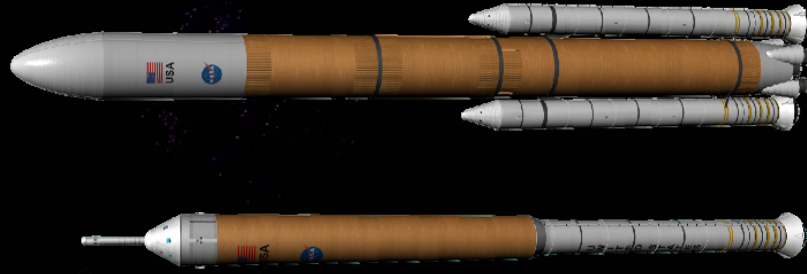


How We Plan to Return to the Moon

Launch Systems



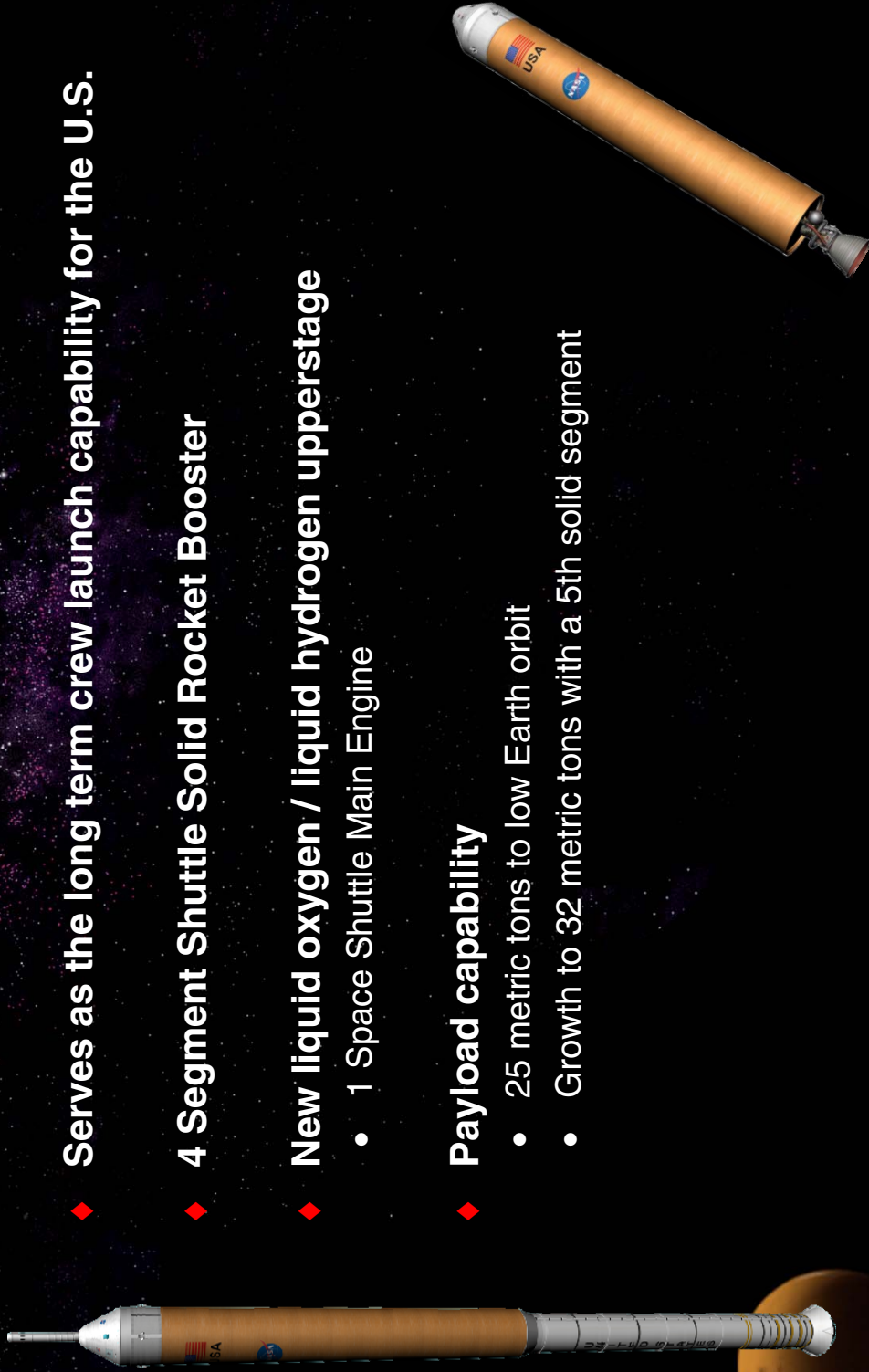
- ◆ Continue to rely on the EELV fleet for scientific and International Space Station cargo missions in the 5-20 metric ton range to the maximum extent possible.
 - New, commercially-developed launch capabilities will be allowed to compete.
- ◆ The *safest, most reliable, and most affordable* way to meet exploration launch requirements is a system derived from the current Shuttle solid rocket booster and liquid propulsion system.
 - Capitalizes on human rated systems and 85% of existing facilities
 - The most straightforward growth path to later exploration super heavy launch needs.
 - Ensures national capability to produce solid propellant fuel at current levels.
- ◆ 125 metric ton lift capacity required to minimize on-orbit assembly and complexity – increasing mission success
 - A clean-sheet-of-paper design incurs high expense and risk.
 - EELV-based designs require development of two core stages plus boosters - increasing cost and decreasing safety/reliability.
 - Current Shuttle lifts 100 metric tons to orbit on every launch.
 - 20 metric tons is payload/cargo; remainder is Shuttle Orbiter.
 - Evolution to exploration heavy lift is straightforward.
 - 125 metric ton capability
 - Lower production costs
 - Easier to human-rate if needed



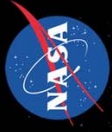
Crew Launch Vehicle



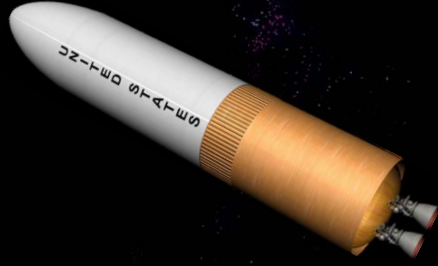
- ◆ Serves as the long term crew launch capability for the U.S.
- ◆ 4 Segment Shuttle Solid Rocket Booster
- ◆ New liquid oxygen / liquid hydrogen upperstage
 - 1 Space Shuttle Main Engine
- ◆ Payload capability
 - 25 metric tons to low Earth orbit
 - Growth to 32 metric tons with a 5th solid segment



Lunar Heavy Cargo Launch Vehicle



- ◆ **5 Segment Shuttle Solid Rocket Boosters**
- ◆ **Liquid Oxygen / liquid hydrogen core stage**
 - Heritage from the Shuttle External Tank
 - 5 Space Shuttle Main Engines
- ◆ **Payload Capability**
 - 106 metric tons to low Earth orbit
 - 125 Metric tons to low Earth orbit using earth departure stage
 - 55 metric tons trans lunar injection capability using earth departure stage
- ◆ **Cargo with later evolution to crew if needed**



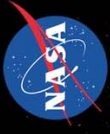
Earth Departure Stage

- ◆ **Liquid oxygen / liquid hydrogen stage**
 - Heritage from the Shuttle External Tank
 - J-2S engines (or equivalent)
- ◆ **Stage ignites suborbitally and delivers the lander to low Earth orbit**
 - Can also be used as an upper stage for low-earth orbit missions
- ◆ **The CEV later docks with this system and the earth departure stage performs a trans-lunar injection burn**
- ◆ **The earth departure stage is then discarded**

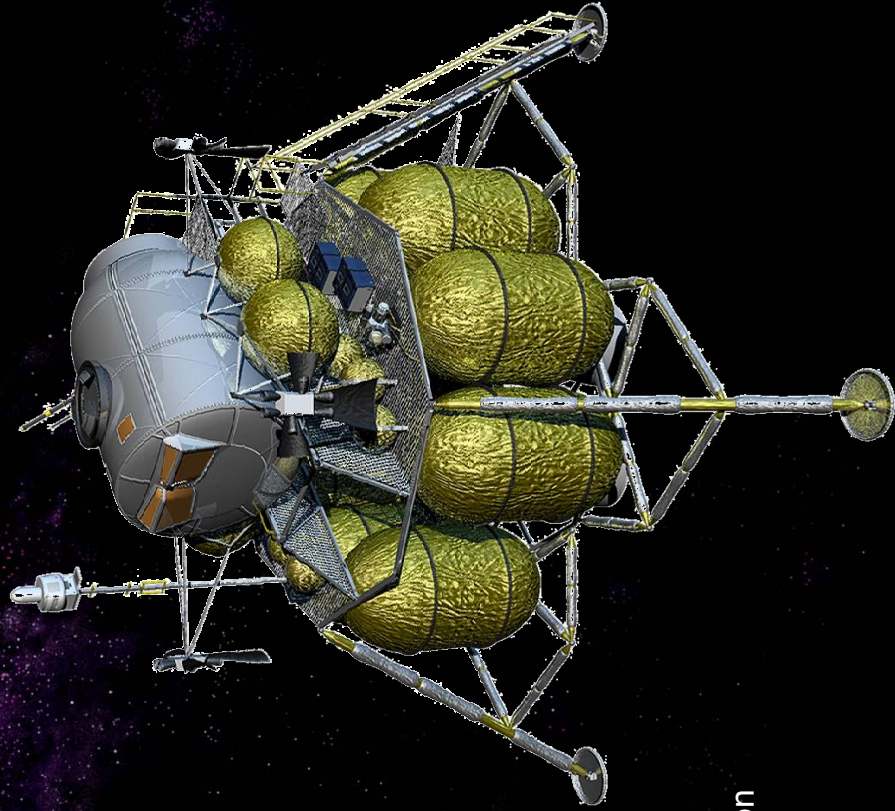


How We Plan to Return to the Moon

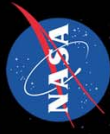
Lunar Lander and Ascent Stage



- ◆ **4 crew to and from the surface**
 - Seven days on the surface
 - Lunar outpost crew rotation
- ◆ **Global access capability**
- ◆ **Anytime return to Earth**
- ◆ **Capability to land 21 metric tons of dedicated cargo**
- ◆ **Airlock for surface activities**
- ◆ **Descent stage:**
 - Liquid oxygen / liquid hydrogen propulsion
- ◆ **Ascent stage:**
 - Liquid oxygen / liquid methane propulsion



ISS – Moon – Mars Architecture Linkages



- 3 to 6 crew + payload
- Crew rotation
- ISS cargo

Crew Exploration Vehicle

- 4 crew Earth-moon transfer

- Mars 6 crew departure and return

Earth-to-Orbit Transportation

- Safe crew launch
- 125 mt-class Heavy Payload Launch
- Large Volume Payloads

- Safe crew launch
- Multiple, Heavy Payload Launches
- Large Volume Payloads

Technology Maturation

- ISRU Systems
- Oxygen-Methane propulsion (CEV SM, LSAM ascent)

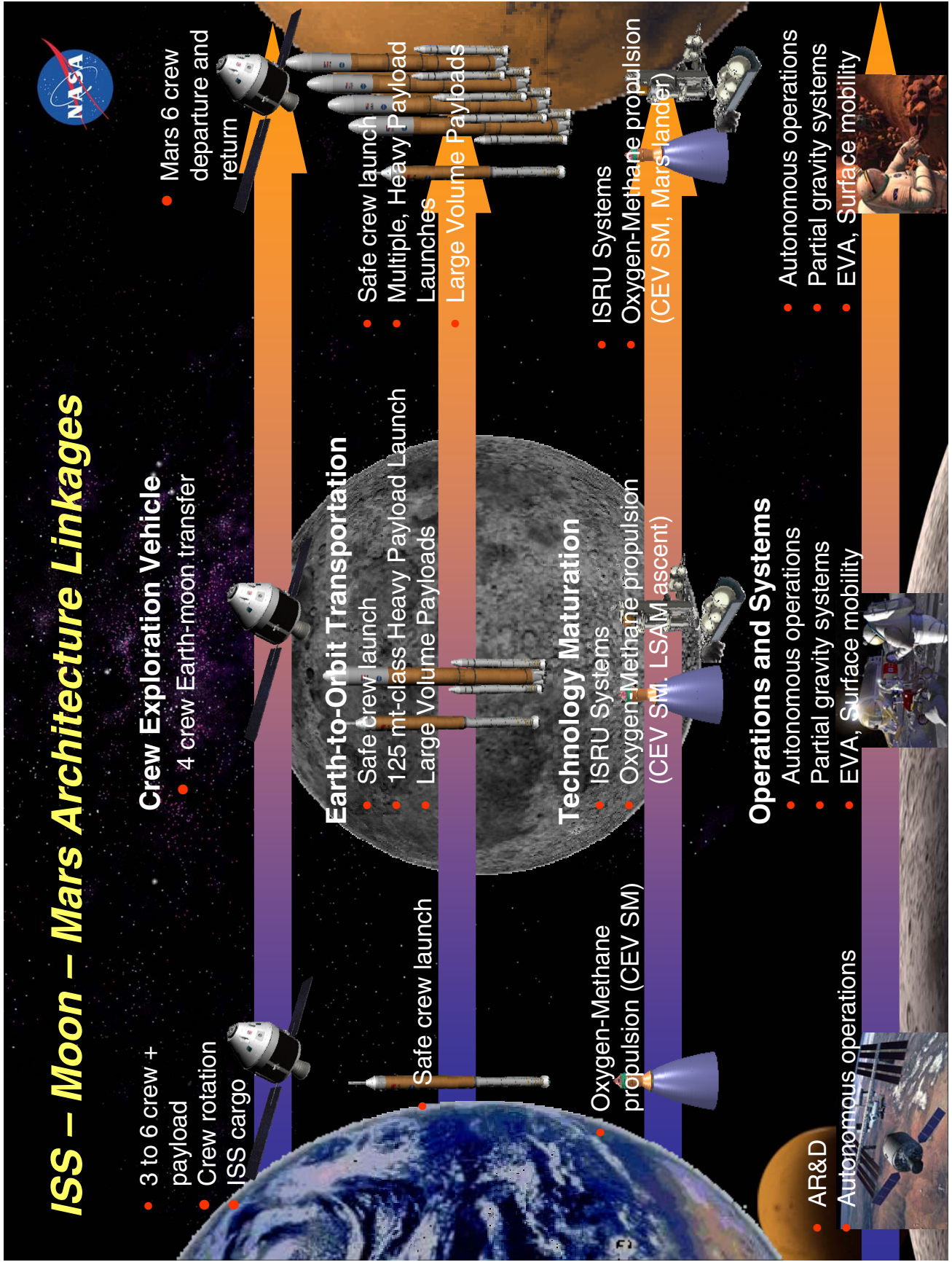
- ISRU Systems
- Oxygen-Methane propulsion (CEV SM, Mars lander)

Operations and Systems

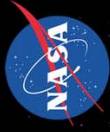
- Autonomous operations
- Partial gravity systems
- EVA, Surface mobility

- Autonomous operations
- Partial gravity systems
- EVA, Surface mobility

- AR&D
- Autonomous operations



Potential Commercial Opportunities



- ◆ **Commercial services for space station crew/cargo delivery and return**
- ◆ **Purchase launch / communications services as available**
- ◆ **Innovative programs to encourage entrepreneurs**
 - Centennial challenges prizes
 - Low-cost sub-orbital and orbital launch demo
 - Independent space station cargo re-entry demo
 - Independent crew transport demo
 - Space station cargo pathfinder demo
- ◆ **Propellant delivery to low Earth orbit for lunar missions**
 - Propellant depot in low Earth orbit
 - Propel earth departure stages/lunar lander after on-orbit transfer
 - Continual commercial replenishment as available
 - Government guaranteed purchase on delivery a certain price



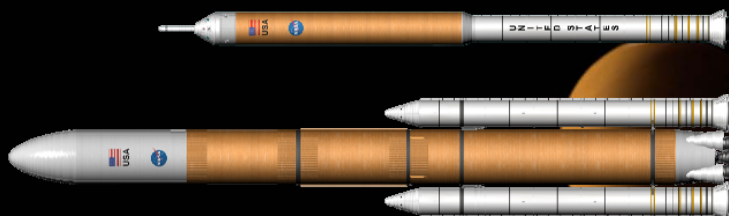
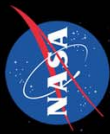
Potential International Opportunities



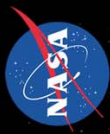
- ◆ Continue International Space Station cooperation re-focused on human exploration
- ◆ Purchase of additional international partner transportation assets for the space station
- ◆ Coordination of lunar robotic pre-cursor missions
- ◆ Cooperate on variety of lunar surface systems
 - Habitats
 - Rovers
 - Power and logistics
 - Science and in-situ resource utilization equipment
- ◆ Provide alternate transportation resources
- ◆ Transportation of international astronauts on the CEV
- ◆ Cooperation on Mars pre-cursor/science missions
- ◆ Preparation for joint human Mars missions

A Safe, Accelerated, Affordable and Sustainable Approach

- ◆ **Meet all U.S. human spaceflight goals**
- ◆ **U.S. system capable of servicing the International Space Station**
- ◆ **Significant advancement over Apollo**
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- ◆ **Orderly transition of the Space Shuttle workforce**
- ◆ **Requirements-driven technology program**



Implementing the Exploration Architecture: Transition from ESAS to ESMD



◆ Architecture

- The Exploration Architecture has been defined
- An Exploration Architecture Requirements Document will be finalized in September

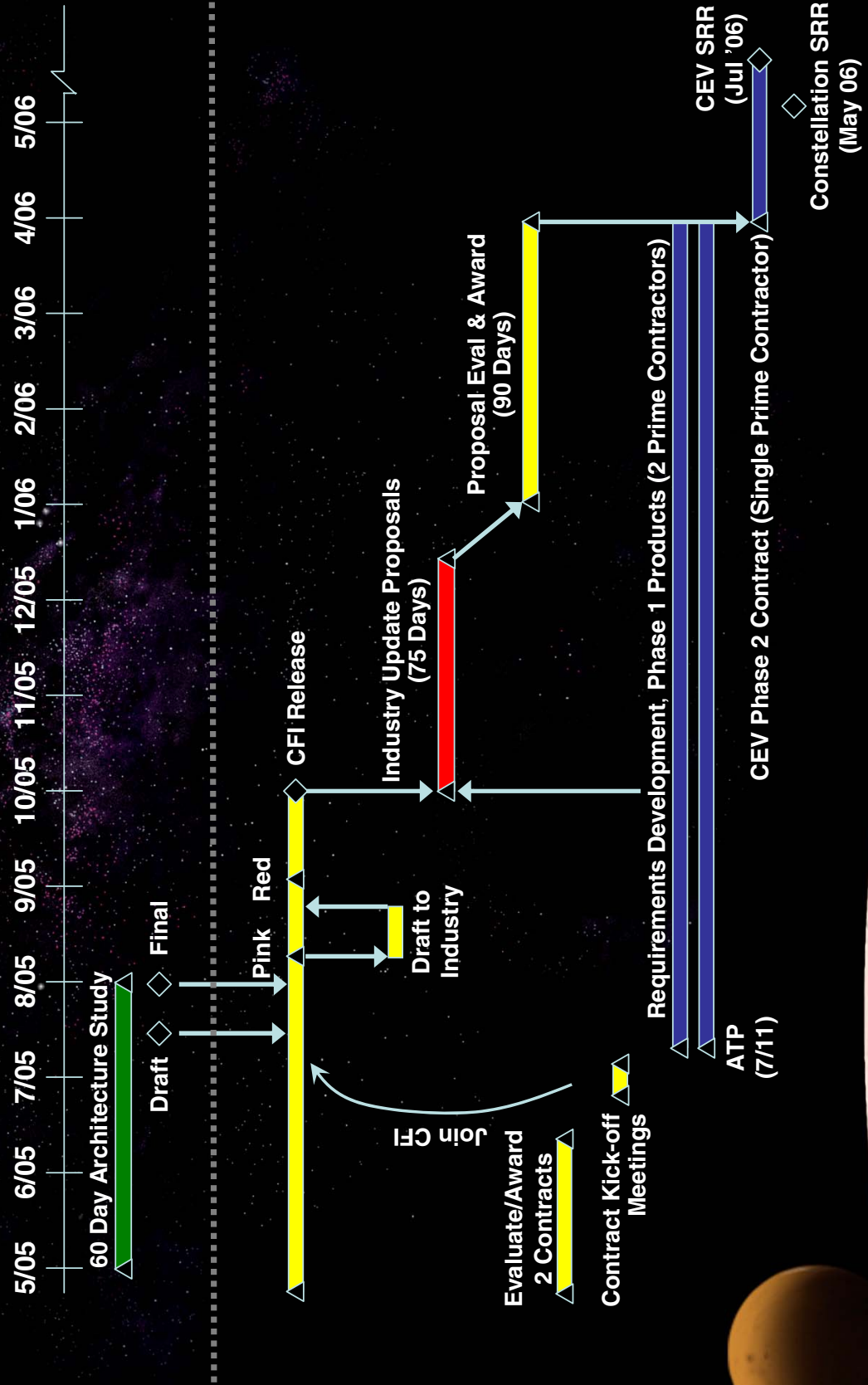
◆ Requirements

- Element specifications for the Crew Exploration Vehicle (CEV), Crew and Cargo Launch Vehicles, and ISS Cargo Delivery Vehicles are in draft; will be validated and baselined by October
- New CEV requirements will be included in the Call For Improvement that be the basis for updated Industry proposals
- Research and Technology programs will be tightly focused on supporting CEV development and the initial return to the moon

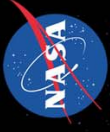
◆ Organization

- A streamlined HQ directorate is being formed
- Program and Project Offices are being established at the NASA centers
- Key individuals from ESAS are joining ESMD

Implementing the Exploration Architecture: Accelerating the Crew Exploration Vehicle



Our Destiny is to Explore!



- ◆ The goals of our future space flight program must be worthy of the expense, difficulty and risks which are inherent to it.
- ◆ We need to build beyond our current capability to ferry astronauts and cargo to low Earth orbit.
- ◆ Our steps should be evolutionary, incremental and cumulative.
- ◆ To reach for Mars and beyond we must first reach for the Moon.

A committed and long term lunar effort is needed, and we need to begin that investment now!

*“We leave as we came, and God willing, as we shall return,
with peace and hope for all mankind.”*

— Eugene Cernan, Commander of
the last Apollo mission



**The United States must lead the expansion of the space
frontier to continue to maintain our world leadership role,
and for the security of the nation.**

**Great nations do great and ambitious things. We must
continue to be great.**